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Radiometric Performance Characterization of the Hyperion Imaging Spectrometer Instrument

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Session II - Hyper Spectral Imaging

SDL/USU Conference on Characterization and Radiometric Calibration for Remote Sensing

November 9, 1999

Earth Observing (EO-1) Spacecraft

TRW

- Part of the NASA New Millennium Program (NMP)
  - Demonstrate Advanced Technologies and Designs
  - Reduce Cost and Improve Quality
- Payloads on the Earth Observing (EO-1) Spacecraft
  - Advanced Land Imager (ALI) - Lincoln Labs
  - Hyperion Imaging Spectrometer - TRW (13 months, $15 M)
  - LEISA Atmospheric Corrector
  - Scientific Applications Satellite - Argentina
  - Landsat 7 EMT+ in same orbit lagging by one hour
- Launched on a Delta 7320 from the WTR, April 2000

Hyperion Imaging Spectrometer

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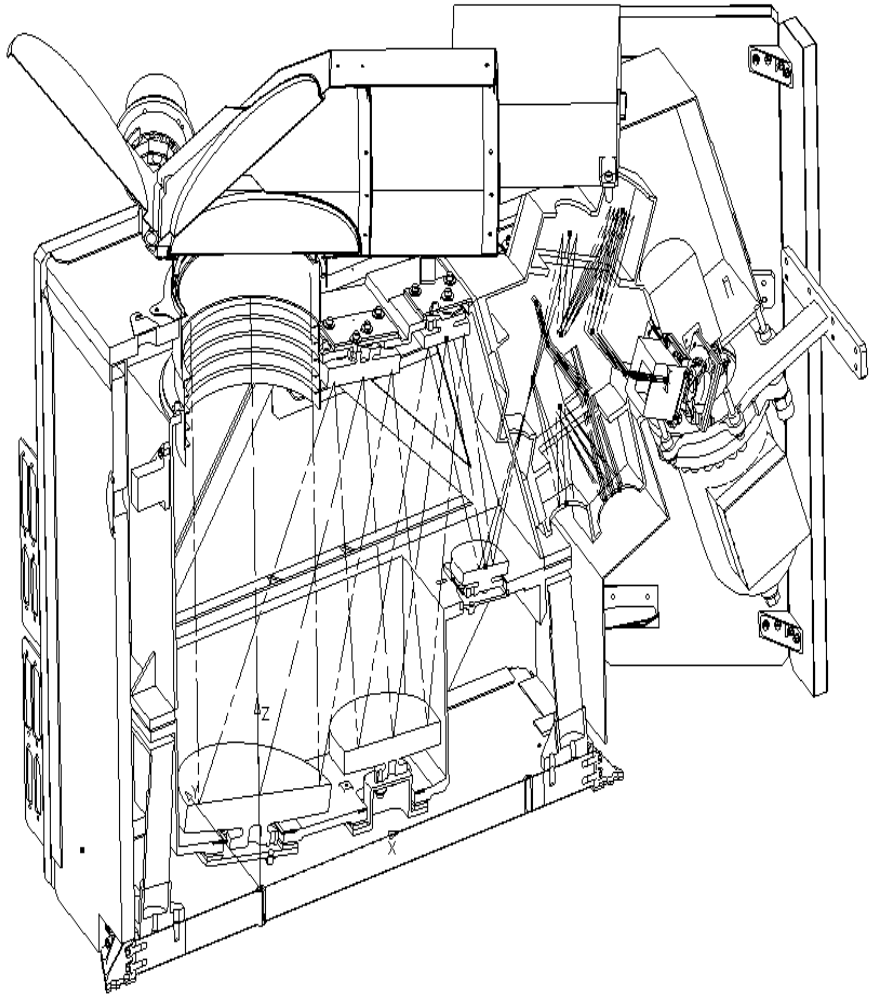
Instrument Parameter Instrument Characteristic	Hyperion
GSD at 705 km Altitude	30 m
Swath Width (km)	7.5 km
Spectral Coverage [μm]	0.4 - 2.5
70 VNIR Channels	
152 SWIR Channels	
Entrance Aperture	12.5 cm
On-orbit Life	1 year (2 goal)
IFOV	42.5 μrad
Spectral Channels	220
Spectral Bandwidth	10 nm
Data Quantization	12-bit
Instrument Weight	49 kg
Instrument Power Consumption Average	78 Watts Orbit



Radiometric Quantities to be Characterized

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- FPA Rectilinearly
  - Cross-Track Spectral Alignment (CTSA)
  - Spatial Co-Registration of Spectral Channels (SCSC)
- Image Quality
  - Cross-track and Along-track MTF
  - Spectral Slit Profile
- Spectral Wavelength Calibration
  - Doped Spectralon Panels
- Linearity and Polarization
- Scene simulation
- Signal to Noise
- Radiometric Calibration

Imaging Spectrometer Radiometric Characterization Facility

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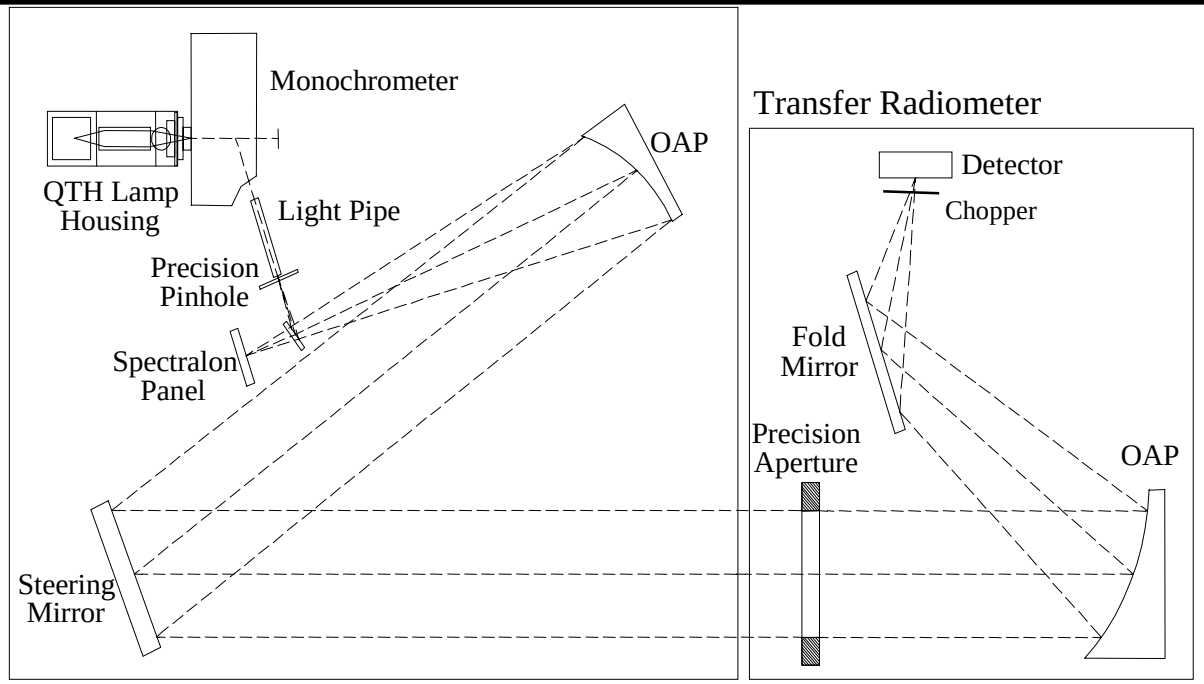
Formerly Known as the MSTB - Upgraded for
Hyperion Characterization

Two modes of Operation:

1) Pinhole, slit and/or Knife Edge at end of light pipe put at focus of OAP
2) End of light pipe is re-imaged onto Spectralon panel.

Both are shown simultaneously in chart without re-imaging optics

Steering mirror is a two axis, fine pointing mirror (± 1–2 μrad) for sub-pixel scanning in spatial dimensions



The transfer radiometer is a removable box for calibration of the Characterization Facility output.

It uses a chopped pyroelectric detector traceable to the TRW primary irradiance scale.

An accurate AΩ is calculated from precision apertures and OAP focal length.

Cross-Track Spectral Alignment (CTSA)

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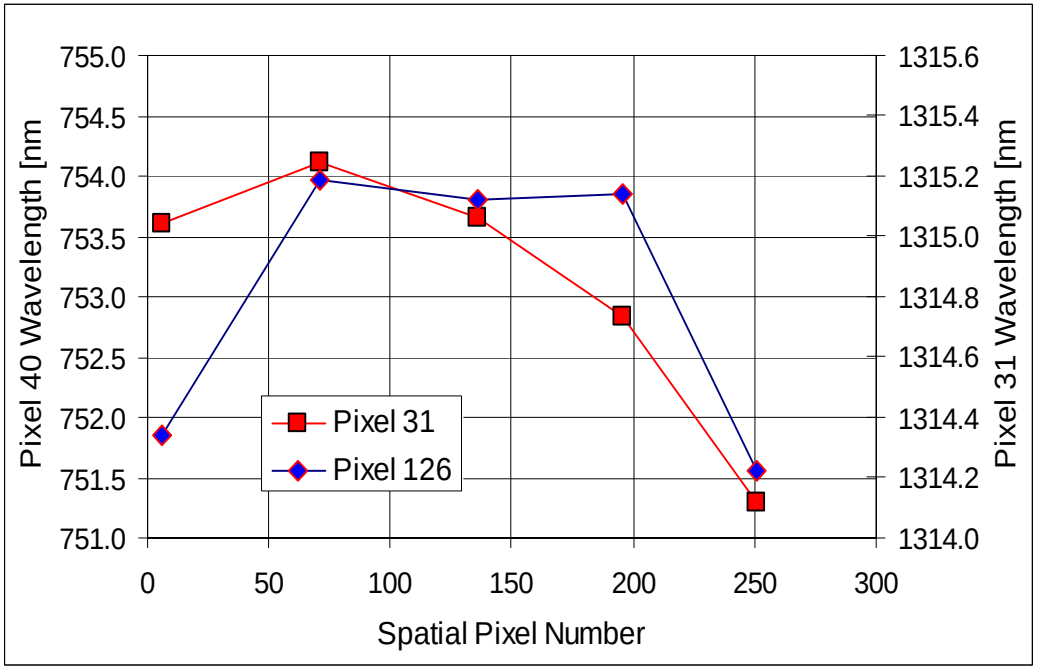
CTSA is a measure of how a monochromatic cross-track line source on the ground falls along a given column of spatial pixels.

It is measured with the monochromator set a given wavelength with a narrow 4 nm exit slit. The end of the light pipe illumination is limited to about 3 spatial pixels. The monochromator is in stepped in a 2 nm wavelength step size through 20 spectral steps.

The center wavelength of each spatial pixel is then derived by centration.

The CTSA is measured at 25 spatial locations across each FPA



VNIR		SWIR	
Wavelength Pixel No.	Δλ [nm]	Wavelength Pixel No.	Δλ [nm]
13	3.51	27	0.45
31	2.77	57	0.17
40	2.92	87	0.57
48	3.15	126	0.98
57	2.70	156	0.45

Spatial Co-Registration of Spectral Channels (SCSC)

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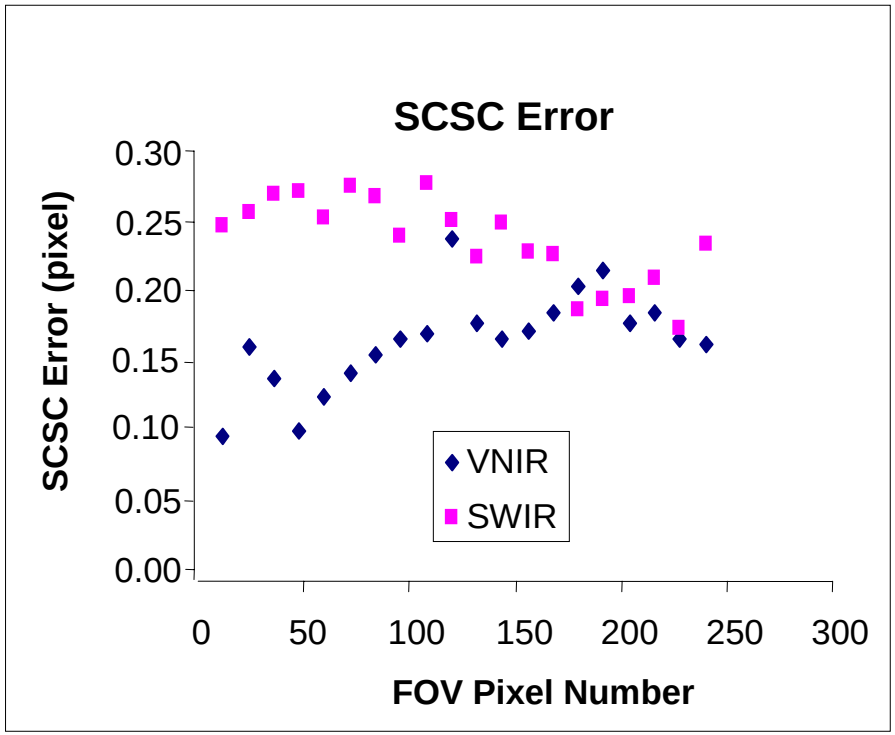
SCSC is the alignment of a broadband point source along a row of spectral pixels. The monochromator is put in zeroth order.



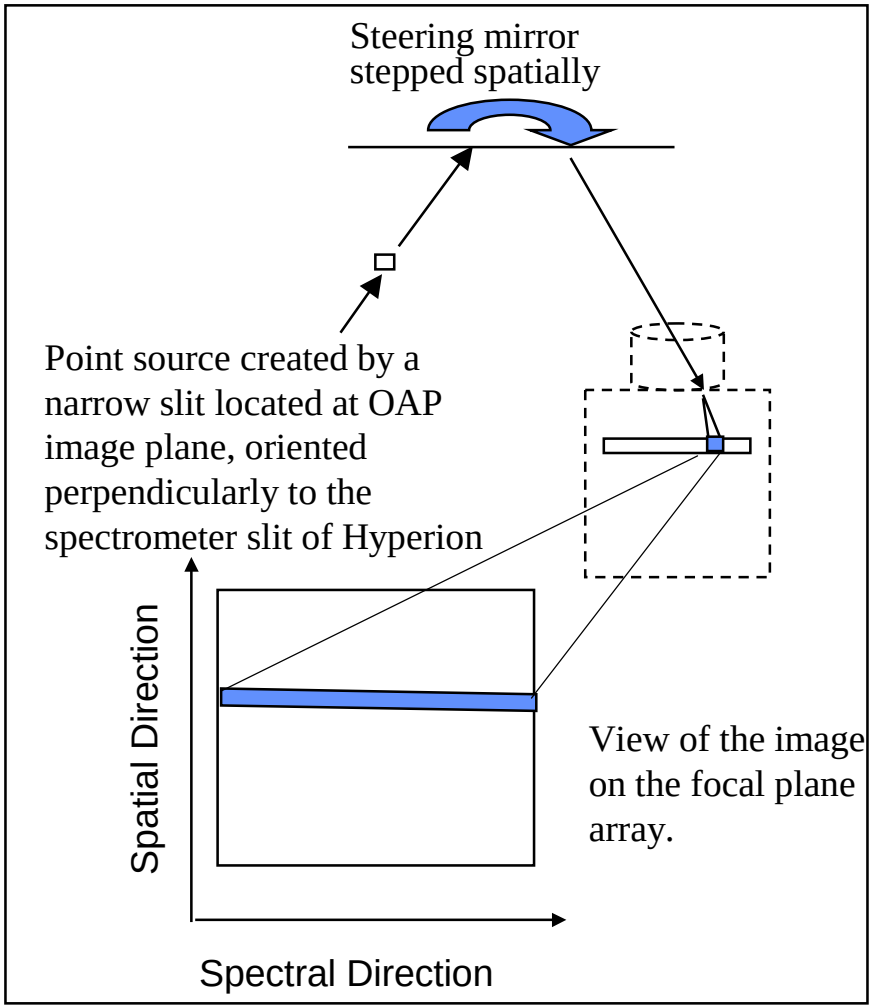


Image Quality - MTF

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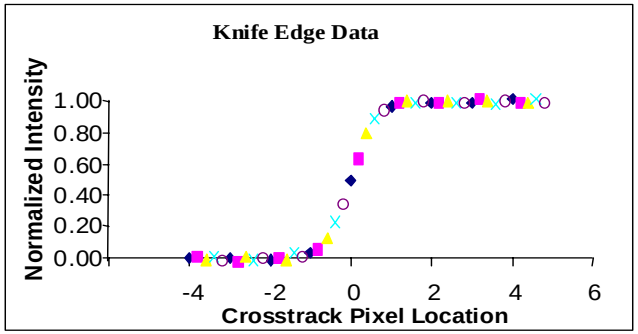
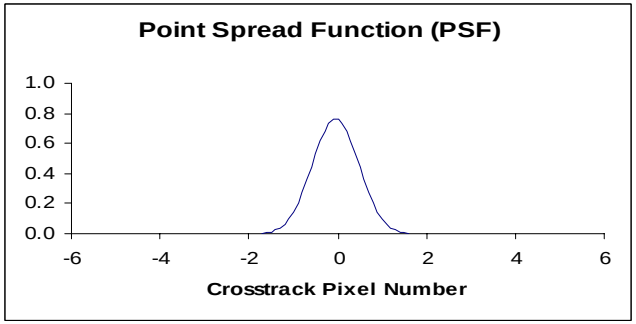
- A knife edge is placed at the end of the light pipe at the focus of the OAP and orientated perpendicular to the Hyperion sensor slit
- The Characterization Facility fine steering mirror is moved in sub-pixel steps to uncover a pixel producing the knife edge data
- The derivative of that curve produces the point spread function (PSF)
- The Fourier transform of the PSF produces the Cross-track MTF (CT-MTF)
- Pixel Quantization effects are added directly by measurement by replacing the knife edge with a slit to map out both sides of the pixel which includes the top-hot function of the pixel
- The Along-track direction MTF equals the convolution of the CT-MTF with the along-track smear produced by the top-hat function of the pixel. The result at the Niquist frequency is a reduction of the CT-MTF by $2/\pi$





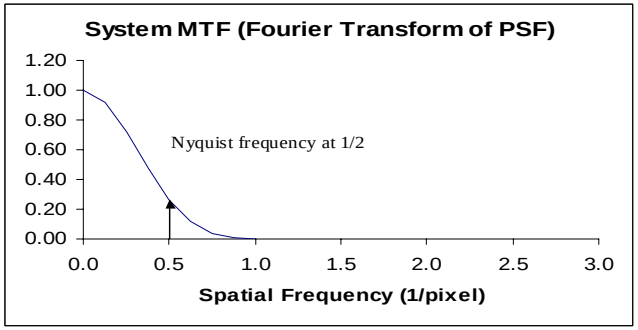


Image Quality - MTF Results

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MTF includes both optical aberrations and pixel sampling quantization.

Spectral line profile is also derived as part of MTF tests

Hyperion Along-Track MTF Results at the Niquist frequency

Cross-track MTF is $\pi/2$ larger.

Wavelength [nm]	FOV Pixel 200	Center FOV	FOV Pixel 20
500	0.29	0.27	0.22
630	0.27	0.28	0.22
900	0.24	0.26	0.22
1050	0.28	0.30	0.28
1250	028	0.30	0.27
1650	0.27	0.27	0.25
2200	0.28	0.27	0.23

Spectral Wavelength Calibration

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High resolution scans of the Holmium and Erbium Oxide doped Spectralon are shown in the next chart.

Two sensor data frames are taken: one from a doped Spectralon panel and one from a high reflectance Spectralon panel.

The ratio of these two frames removes lamp illumination source wavelength variations and sensor response variations.

To derive a calculated curve for the above data, the high resolution scans are convolved with the sensor spectral response function. This degrades the high resolution scans to the lower sensor resolution.

A linear least squares (LLS) regression of the data points with the curve fixes the wavelength calibration of the sensor. Each spatial FOV position is calibrated in wavelength simultaneously for all spectral pixels saving time greatly.

The linear regression at each FOV position allows three constants for wavelength values at the pixel center (i.e. a second order fit in λ versus pixel number). The width of the sensor pixel response function is also allowed to take on a best fit value for the LLS.

The accuracy of the fit is about 0.02 pixels (judgement call based on the width of the standard error minimum of the LLS fit

In-Flight Radiometric Calibration

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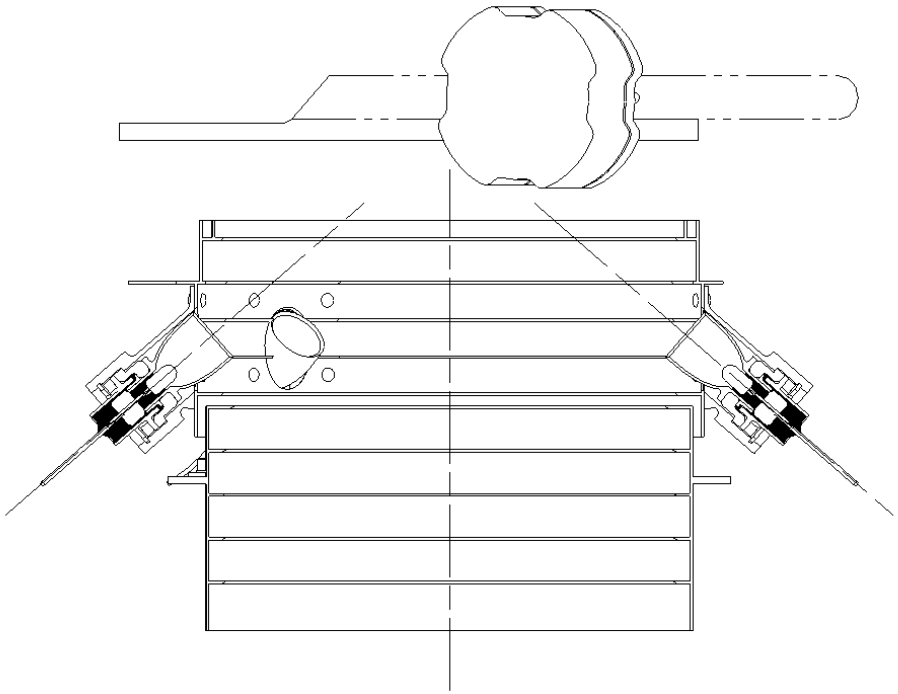

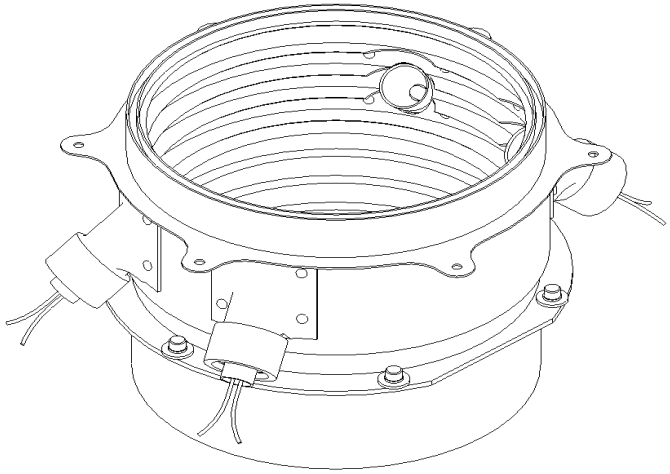

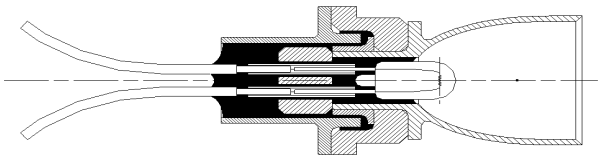

Polarization

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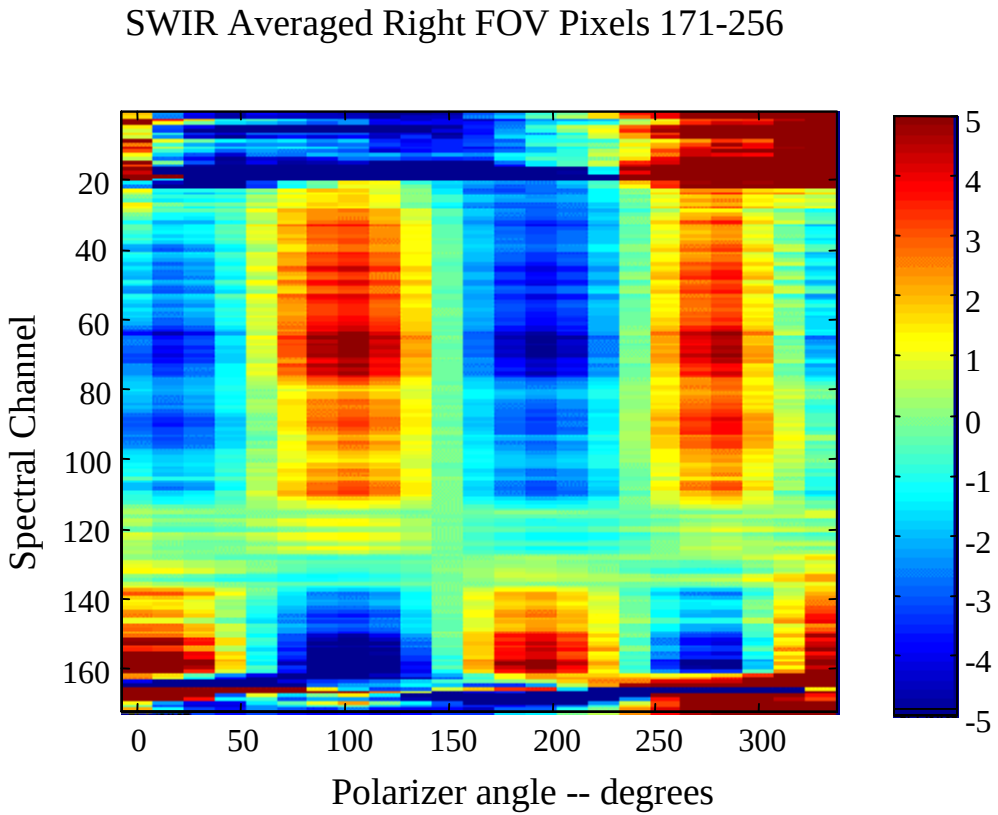
Polarizer located just outside of the vacuum window

Data taken at 15 degree steps in polarization angle

Scene response averaged over spatial channels 171-256 for each spectral channel

Results are in Percent



Scene Simulation

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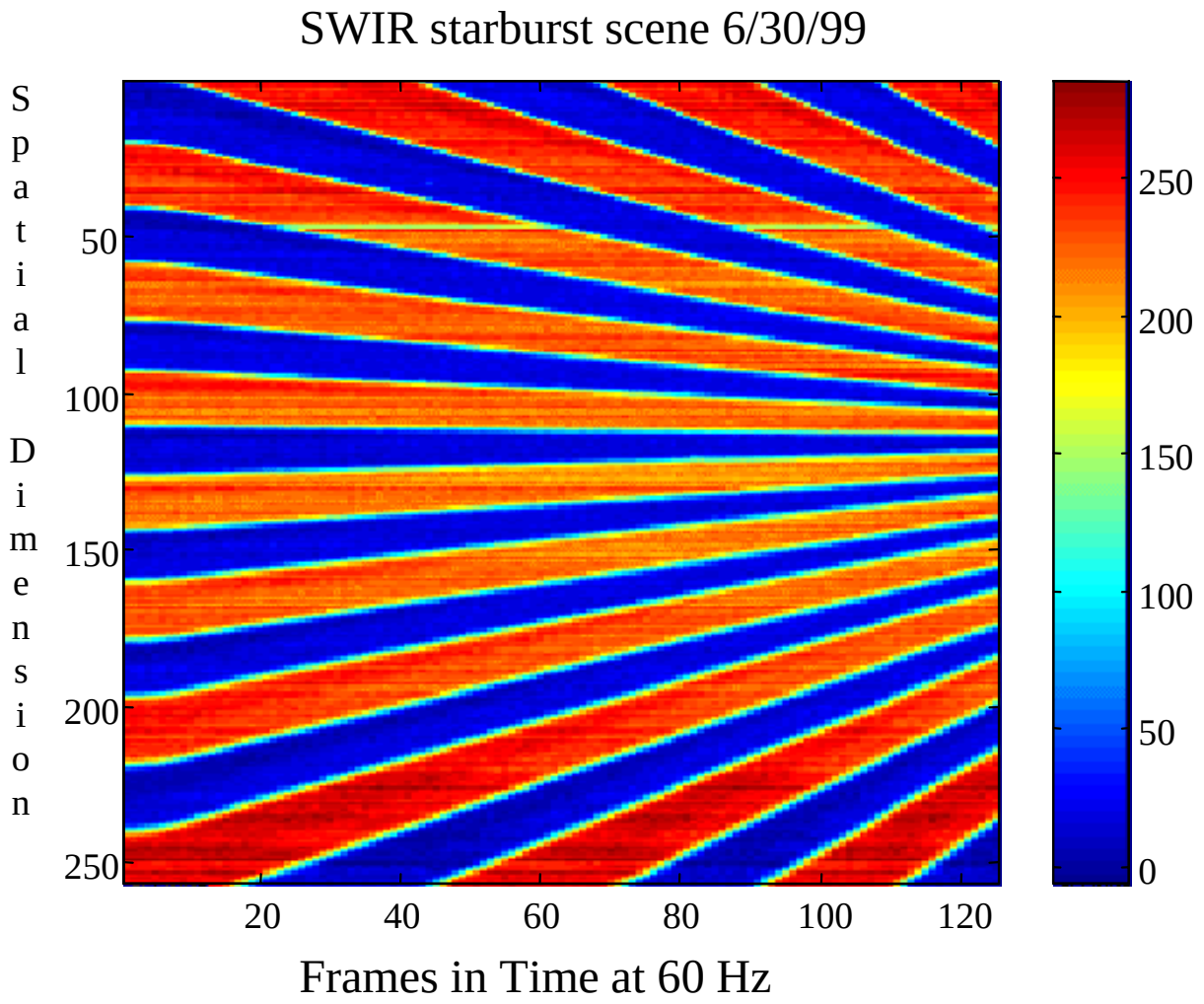
Transparency Starburst target placed at focus of the OAP of the Characterization Facility and moved in the in-track direction at the appropriate rate for 60 Hz frame rate.

The color bar is in sensor counts



Signal to Noise Performance

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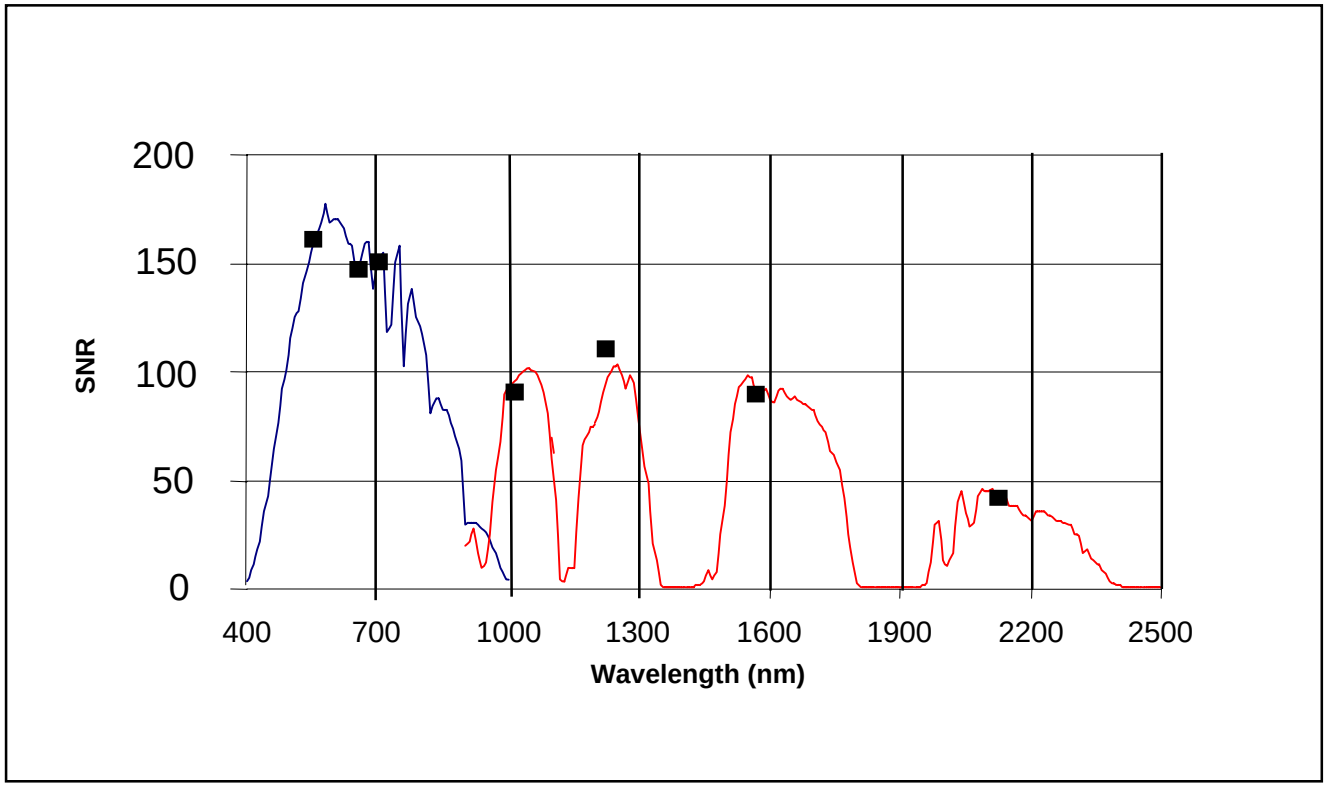

The SNR Model (the curves) was adjusted to match the measured results correcting the model in effect for incorrect predicted FPA performance

Spectralon Panel Assembly Installed

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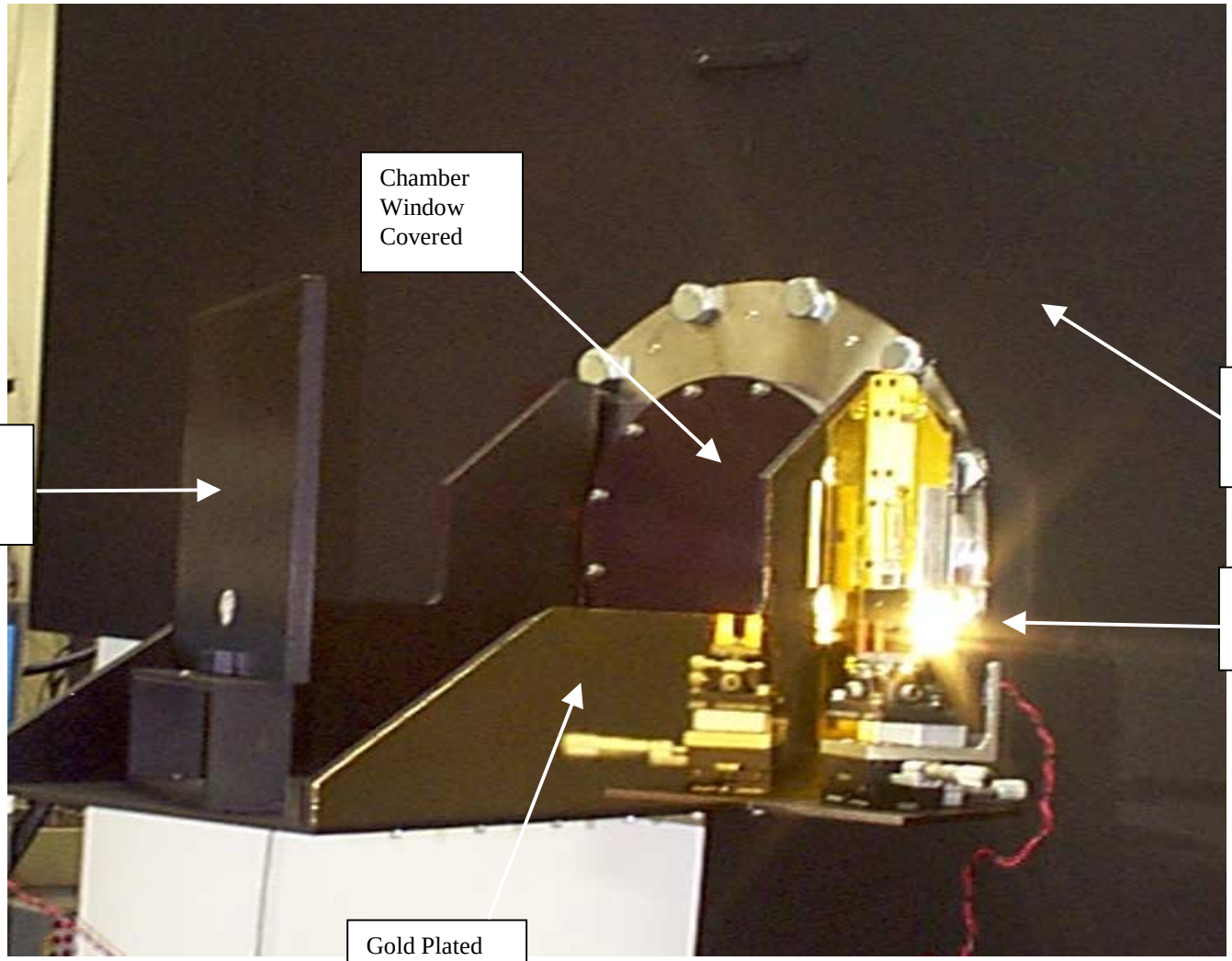

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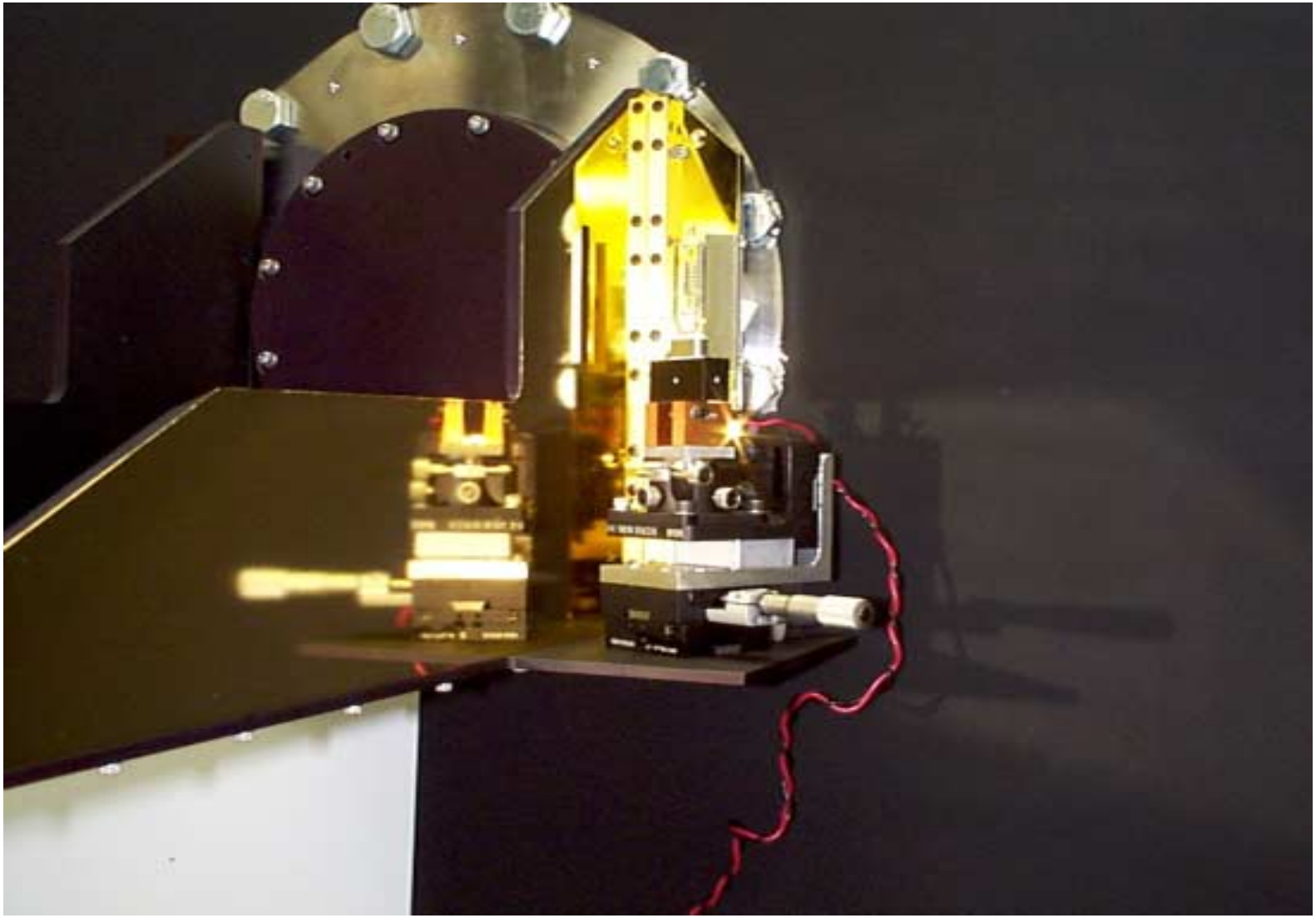

Conclusions

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Upgrades to the TRW Imaging Spectrometer Radiometer Characterization Facility

TRWISRCF {formerly known as the MSTB}

have improved fidelity of the characterization data base generated as a standard set of end-to-end IS performance parameters.

The suite of parameters includes: CSTA, SCSC, Spectral line profile, Image quality (MTF), Spectral wavelength calibration, Polarization, Linearity, Signal to Noise, Scene simulation and Radiometric calibration.

The experience base now includes Lewis IS (SSTI), TRWIS III, Kompsat and Hyperion (EO-1, NMP)